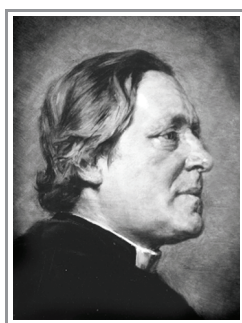


***The Face of the Ocean:* Alphonse-François Renard (1842-1903) and the Rise of Marine Geology**

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The Report on Deep-Sea Deposits based on the specimens collected during the voyage of H.M.S. Challenger in the years 1872 to 1876, signed by John Murray – one of the Naturalists of the Expedition – and Rev. A.F. Renard – Professor of Geology and Mineralogy in the University of Ghent – was published in 1891. This report, which is considered as the founding work of marine geology, may be regarded as a team work implying three exceptional scientists: Sir Wyville Thomson, John Murray and Alphonse-François Renard. This paper focuses on the role of Alphonse-François Renard, who was curator at the Musée Royal d'Histoire Naturelle in Brussels at the time of the initial contacts with the *Challenger Office* in Edinburgh. In 1888, Renard was appointed professor of geology and mineralogy at Ghent University. While several biographies have already narrated Renard's life, a few key moments remained elusive. Some newly consulted documents, such as a set of 52 letters of Alphonse-François Renard to Sir Archibald Geikie kept at the Library of the University of Edinburgh, confronted with archives in Brussels and available literature, shed some new light e.g. on Renard's early discovery of the world of geological science at the Abbey of Maria Laach in the Eifel and on the chronology and circumstances of his stays in Austria and Scotland. By the same token, they

suggest a maybe hitherto overlooked role of Sir Archibald Geikie in the alliance between these three scientists.

The Cruise of the Challenger (1872-1876)

The very first words in George Sarton's *La Synthèse Géologique de 1775 à 1918* (1), published in 1919 in the first post-war issue of *ISIS*, pay tribute to Eduard Suess' *Das Antlitz der Erde* (1909) – *The Face of the Earth* – which he considers as the masterpiece of geological synthesis at the turn of the century¹. In this review, George Sarton identifies three major periods of geological synthesis between the late 18th and the early 20th century, each spanning about half a century. He chose 1775, when Abraham Gottlob Werner started lecturing at the Mining Academy in Freiberg, as the pivotal year between the early youth of geological science and 'adolescence'. The main players in the first period of the 'adolescence' of geological science (1775-1820), according to Sarton, are Werner, Hutton, William Smith, Lamarck, Cuvier and Brongniart. This "*âge héroïque*" is followed by the period of the first syntheses, from 1820-25 to 1870-75: those of Charles Lyell, Leopold von Buch, Alexander von Humboldt and Elie de Beaumont. The second period closes amid the turmoil caused by Darwin's work. Just like the voyage of the *Beagle* (1831-36) had marked in some way the beginning of the second period, it is the cruise of HMS *Challenger* (1872-1876) that would herald the third period.

The brain behind the cruise of the *Challenger* was Charles Wyville Thomson (1830-82), who would become Professor of Natural History in Edinburgh in 1870. It is commonly reported that Wyville Thomson challenged the statement of Edward Forbes, his predecessor at Edinburgh University, who had postulated an 'azoic' zone in the oceans, below 500m. Thomson had observed the variety of animal specimens brought up off the Lofoten islands in Norway from depths well below Forbes' 'azoic frontier'. Moreover a broken telegraph cable between Cagliari and Bone in the Mediterranean, hauled up for repair from depths beyond 2000m, had been found amply colonized by animals which evoked fossil communities.

¹ Sarton had read the French translation of Suess' monumental work: *La face de la Terre*, edited by Emmanuel de Margerie (2).

What is less commonly reported, but stands as a prominent statement in the first pages of *The Depths of the Sea* (3), is that Thomson soon had rallied to the ideas of Darwin, Wallace and Haeckel. These stood in opposition to most of the ‘laws’ formulated by Forbes, which commonly argued for the immutability of species. In a letter of May 30th, 1868 addressed to William Benjamin Carpenter, member of the Royal Society, Thomson argues that dredging the depth of the seas might reveal the affinity between presently living species and fossil ‘parents’. The crinoids found on telegraph cables, for instance, could be traced to species which thrived in Jurassic times. Thomson’s argument was remarkably successful. Two months after his writing, on August 4th, 1868, he could sail from Pembroke on board of HMS *Lightning* to dredge the flanks of a ridge between Scotland and the Faeroe². A more seaworthy vessel – HMS *Porcupine* – would be made available by the Admiralty in 1869.

Soon, the debate would amplify. Both the soundings across the deeper North Atlantic in view of the telegraph connection between Europe and America and the first dredges of the *Lightning* (1868) and the *Porcupine* (1869) had brought to the surface a calcareous ooze, almost entirely consisting of shells of foraminifera (*Globigerina*). The resemblance with chalk, commonly found for instance in the cliffs of Folkestone, was so striking that Thomson soon boldly referred to the ‘modern chalk’ of the Atlantic. A full chapter in his book *The Depths of the Sea* deals with the ‘present-day formation of chalk’. Thomson acknowledges a vivid debate with Charles Lyell and Roderick Murchison, who had criticized an early statement of him suggesting that the “modern chalk” found in the Atlantic Ocean should be regarded as ‘the’ Cretaceous chalk, still in formation in the present deep ocean – *mutatis mutandis*, an early concept of a ‘Jurassic (or Cretaceous) Park’?

Wyville Thomson’s bold statements however paid off, and he obtained from the Royal Society and the Admiralty a three-masted, square-rigged corvette, HMS *Challenger*, to sail for a prolonged and ambitious voyage of exploration of the abyss across the world. The *Challenger* expedition (1872-1876) would open the era of modern oceanography. A tremendous amount of data, collected world-wide and to the greatest depths ever, would

² This ridge would later be named the Wyville-Thomson Ridge.

become available to scientists. The exploitation of this treasure – through an international ‘network of excellence’ *avant la lettre* – was unprecedented. Experts from many parts of the world were solicited and worked for years in *Challenger Lodge*, a stylish Georgian House built in Edinburgh in 1825, possibly to the design of William Playfair. Among these foreign experts were the Belgian malacologist Paul Pelseneer (1863-1945) and the geologist and mineralogist Alphonse-François Renard (1842-1903), at that time curator at the Royal Museum of Natural History in Brussels. The comprehensive and influential *Report on Deep-Sea Deposits* (4) would be signed by John Murray – *one of the Naturalists of the Expedition* – and Rev. A.F. Renard – *Professor of Geology and Mineralogy in the University of Ghent*.

The studies which led to the *Report on Deep-Sea Deposits* laid the base for a nomenclature of deep-sea sediments, still largely in use (5). This classification enabled Murray and Renard to draft the very first map of the deep-sea sediments of the world oceans (6). In addition, over a period of 20 years, Alphonse-François Renard would analyze the composition of the rocks of all islands visited by the *Challenger*, publishing his observations in not less than 20 papers. Many of these islands had been visited and sampled by Darwin with the *Beagle*, and Renard systematically confronted the *Challenger* data with Darwin’s observations. While already showing the symptoms of the illness which would prove fatal, Alphonse-François Renard would still finalize and publish the first French translation (7) of Darwin’s Part II of *The geology of the voyage of the Beagle – Geological observations on the volcanic islands visited during the voyage of H.M.S. Beagle* (8). The remarkable preface of this book may be read as his scientific and philosophical testament.

Alphonse-François Renard’s scientific achievement in marine geology over 25 years, from 1876 to 1901, encompasses both the study of deep-sea sediments – as expression of processes in the ocean – and the study of the volcanic and metamorphic rocks outcropping on oceanic islands – as a window on the dynamics of the Earth’s mantle. We might say that at the dawn of the 20th century, Alphonse-François Renard’s global and holistic geological research over the ocean realm has contributed to lift the veil of the ‘*Face of the Ocean*’. A major difference between Renard’s *opus* and Eduard Suess’ *Face of the Earth* is that the latter work, also representing

an impressive effort over many years, is by essence a global synthesis, an impressive, solitary and visionary compilation of the science of the Earth. Alphonse-François Renard's work, in contrast, has the merit of being analytical throughout, and as regards the study of the deep-sea sediments, it was modern team work with John Murray. Yet, like Suess, Renard personally signed several thematic and historical reviews. It is widely recognized that the *Report on Deep-Sea Deposits* has laid the foundation for the sedimentology of the deep ocean floor (Seibold and Berger 1982) (9). Eduard Suess himself amply refers to Murray and Renard's work in *Das Antlitz der Erde*. Hence, it is a more than remarkable observation that George Sarton, whose *Synthèse Géologique de 1775 à 1918* clearly argues for a careful lecture of Eduard Suess' *magnum opus* and who refers to the cruise of the *Challenger* as a milestone – even occasionally citing John Murray – ignores in his *Synthèse Géologique* both Alphonse-François Renard and the seminal *Report on Deep-Sea Deposits*.

The shaping of a Jesuit

The life of Alphonse-François Renard has been narrated by several authors. We can cite the biographies or obituaries written by Georges Kaiser (10), Sir Archibald Geikie (11, 12), Charles Fiévez (13), Henriette Renard (14), Paul Mansion (15), H. Buttgenbach (16), André Roekeloos (17), R. Van Tassel (18), Guy T. Houvenaghel (19, 20), Leopold Walschot (21) and a few anonymous texts (22, 23).

Alphonse-François Renard was born of modest parentage in Renaix (Ronse), in Eastern Flanders, on September 27th, 1842. He received his early education in his native town, at the primary school and the St. Antonius College. At the age of 12, he would have been recruited as a clerk to the textile manufacturer Vandeputte in Renaix, though André Roekeloos claims a more adventurous track, as the young Alphonse would have tried to escape and sign on – in vain – as a ship's boy on an Antwerp vessel, while his brother Alfred would have entered the factory. In 1856, through intercession of a Jesuit, Alphonse got access to the Episcopal College in Renaix. Four years later, he proceeded with his humanities at the Jesuit College in Turnhout. In 1863, Alphonse-François Renard entered the Noviciate of the Society of Jesus in Drongen, close to Ghent. From 1866 to

1870, he acted as superintendent and teacher of English at the Collège de la Paix in Namur. In 1870, he was sent to the Jesuit Training College at the Abbey of Maria Laach, for studying philosophy and science. The Jesuit *Collegium Maximum* in Maria Laach had been installed in 1864, in the premises of the old abbey which had been founded in 1093 as a priory of the Benedictine Affligem Abbey (Brabant, Belgium). The *Collegium Maximum* was staffed by some 40 Jesuits, most of them lecturing to some 120 students.

The shaping of a geologist

The Abbey of Maria Laach occupies an exceptional site on the rim of the Laacher volcanic lake, well fitted to kindle in any receptive student an interest in geology. A mere walk around the lake offers exposures of both Devonian sedimentary strata and Quaternary volcanic tuffs (24). Within walking distance, the pumice exploitation of the Wingertsberg offers a stunning cross section through the deposits of the gigantic explosion of the Laacher volcano, barely some 13.000 years ago old. There is no doubt that the focus at the *Collegium Maximum* was on theology and philosophy. Still, such exceptional setting could only spark the interest of both Jesuit lecturers and scholars for natural science, and geology in particular. Jozef Kolberg, P. Martinus Bischoff and Wilhelm Graffweg were his lecturers in natural sciences (25). Jesuit L. Dressel published in 1871 the “Geognostisch-geologische Skizze der Laacher Vulkangegend” (26), while Theodor Wolf, who would later (1873) emigrate to lay the base of geological research in Ecuador, apparently had developed advanced equipment for teaching mineralogy, petrography and geology, by the time of Renard’s stay (12).

The Franco-Prussian war (July 1870-May 1871) would shorten Renard’s first study period in Maria Laach. He returned to Belgium and became superintendent and teacher of German in the Jesuit College of Tournai (Doornik). When the war had ceased in 1871, he returned to Maria Laach. In 1872-73 however, the Jesuit Training College of Maria Laach had to close and Jesuits exiled under pressure of Bismarck’s *Kulturkampf*. Rather than joining Theodor Wolf and two fellow Jesuits to Ecuador, Renard returned to Belgium to proceed with studies in philosophy and theology in

Louvain (Leuven). Quite soon, in 1873-74, he became lecturer in chemistry and in mineralogy at the College of Jesuits in Leuven.

In association with Charles de la Vallée-Poussin, professor of geology and mineralogy at the Catholic University of Leuven, he submitted in 1874 to the Belgian Academy a substantial monograph on the mineralogical and stratigraphical characters of the rocks 'named plutonic' in Belgium and the French Ardennes. This monograph would be published in 1876 as a *Mémoire couronné* of that institution (27).

The shaping of a petrologist: Renard and petrographical microscopy

The Memoir published by the Academy (1876) contains ample microscopic work illustrated by beautiful colour reproductions of thin sections of rocks. In the preface, Renard acknowledges the collaboration of Ferdinand Zirkel (1838-1912), who had introduced on the Continent the technique of microscopical petrography developed by Henry Clifton Sorby (1826-1908). Sorby, who had furthered the Edinburgh pioneer work of David Brewster (1781-1868) and William Nicol (1768-1851), had published in 1858 a seminal paper entitled *On the microscopical structure of crystals, indicating the origin of minerals and rocks* (28). As narrated by Jacques Touret (29), it is on a Rhine cruise in 1862 that Ferdinand Zirkel and Hermann Vogelsang (1838-1874) had met Henry Clifton Sorby. Zirkel had published in 1859 a memoir on the volcanic rocks of the Eifel, and in 1864, Vogelsang would likewise submit to the Dutch Society of Geology in Haarlem a memoir on the Eifel volcanics. The Eifel apparently having developed as a testing ground for advanced petrographical studies in Germany in the sixties, it is no surprise that Renard would have found the state of the art in this discipline upon arrival in 1870 in Maria Laach. Renard, who soon would patiently prepare his own thin sections of rocks of the Ardennes for microscopical investigation in the years 1872-74, can thus take his place among the first disciples of Zirkel on the Continent. As reported by Jacques Touret, the 'rising star' of French petrography Ferdinand Fouqué (1828-1904) would first get acquainted with the technique one year later, in 1873, while visiting Harry Rosenbusch (1836-1914) in Heidelberg (29).

In April 1876, Renard presented a summary of the Ardennes study at the Royal Microscopical Society in London: *Some results of a Microscopical Study of the Belgian Plutonic Rocks* (30). In this conference, he proved his command of the most advanced techniques of microscopy by moving – in the footsteps of Sorby – the study of quartz crystals to the frontiers of fluid inclusion analysis and the calculation of the temperature and pressure at the moment of crystallization. But microscopical petrography would for Renard not only become a powerful technique: it would become a passion, as expressed a few years later in lyric terms at an evening conference of The Royal Institution of Great Britain in London, which had as theme ‘*La Reproduction Artificielle des Roches Volcaniques*’ (31):

Pouvoir retracer avec une stricte fidélité dans une masse rocheuse, où l’œil nu ne découvre qu’un amas indistinct et tout d’une venue, la marche de la cristallisation, pénétrer dans ce admirable tissu des produits volcaniques où, dans un centimètre cube, viennent s’agencer des millions de polyèdres, déterminer avec une précision mathématique la nature de chacun de ces corps infiniment petits, les prendre à leur naissance, les suivre jusqu’à leur entier développement, retrouver la trace de toutes les modifications qu’ils ont pu subir sous l’influence des agents physiques et chimiques, voilà ce que ce puissant mode d’investigation, l’analyse microscopique, a permis de réaliser.

The conference in London in April 1876 was perfectly timed: one month later, May 24th, *H.M.S. Challenger* anchored at Spithead, concluding her voyage and delivering to science a bulk load of sediments and rocks, urging for analysis.

Wyville Thomson and Alphonse-François Renard

In April 1877, Renard presents a second conference at the Royal Microscopical Society in London: *On the Mineralogical Composition and the Microscopical Structure of the Belgian Whetstones* (32), which would earn him a second *Mémoire couronné* of the Academy in 1878. In July 1877, he gets appointed as Curator at the Royal Natural History Museum of Brussels. A few months later, he is ordained a priest (1877).

In those years, Renard apparently had not escaped the fever of the debates on 'calcareous ooze', triggered by Wyville Thomson. His personal interest for what we nowadays commonly would name 'the carbonate factory' had been sparked by the microscopical study of Belgian Carboniferous limestone. October 28th, 1877, he applies to the director of the Museum, Edouard Dupont, for a travel of some 8 days to London:

Monsieur le Directeur,

Les recherches que je fais en ce moment sur les roches du calcaire carbonifère de Belgique, m'ont montré que les organismes microscopiques, principalement les foraminifères jouent un rôle considérable dans la formation de ces roches. Malheureusement nous ne possédons en Belgique aucun des échantillons types avec lesquels nous puissions identifier les foraminifères que je découvre et personne ne s'est occupé dans notre pays de la détermination de ces organismes du calcaire Carbonifère. Dans l'intérêt de mes travaux je crois qu'il est important d'aller étudier en Angleterre les types qui ont servi aux savants anglais, auxquels on est redevable des connaissances que nous possédons de ces foraminifères du terrain Carbonifère.

On November 9th, 1877, he reports about his visit to William Kitchen Parker (1823-90) in London:

Je suis arrivé à Londres lundi matin et j'ai commencé immédiatement avec M. Parker l'étude des foraminifères. J'espère avoir fini dans le courant de la semaine prochaine la révision de toutes les formes qui se rapportent aux foraminifères du terrain Carbonifère et je compte me rendre alors à Newcastle on Tyne pour examiner la collection de M. Brady qui s'est spécialement occupé de la question qui nous intéresse. M. Parker connaît surtout les foraminifères tertiaires et récents. Ce savant est Darwiniste à un degré exceptionnellement élevé; il est cependant trop exalté pour m'émouvoir. Je n'ai pas encore vu Ramsay mais on m'a fait entrevoir que je n'aurais pas de difficulté à me procurer par voie d'échange les roches types du Carbonifère anglais.

It is tempting to speculate that Renard next proceeded from Newcastle on Tyne to Edinburgh, to meet for the first time Wyville Thomson and see the collections of the Challenger. Indeed, Edouard Dupont reports in a letter of 1878:

Déjà à l'automne dernier, il s'était rendu à Edimbourg pour examiner les roches calcaires recueillies par le Challenger afin de mieux se rendre compte des circonstances qui avaient présidé au dépôt de nos grands massifs de calcaire.

Les organismes microscopiques de l'Océan et leur action en Géologie (1878)

Straight after his visit to Edinburgh in fall 1877, Renard demonstrates his remarkable capacity to assimilate and directly exploit new information in a substantial review paper: *Les organismes microscopiques de l'Océan et leur action en Géologie* (33). Starting from the discoveries made by the *Challenger* team and published in preliminary reports and papers by John Murray, Renard reviews and discusses a wide spectrum of literature sources, back to Ehrenberg (1843, 1853) and Huxley (1858), to discuss the nature and role of phytoplankton (coccoliths, diatoms) and zooplankton (foraminifera, radiolaria) in geology. An interesting early debate relates to the depth where the zooplankton would thrive: at the surface or at the seafloor, where the shells were found. Trawling fine-mazed plankton nets at different depths, John Murray had been able to address the question, comparing the shells of live species close to the surface with the shells collected on the seabed and coming to the conclusion of a significant transport from the surface to the seabed.

Noteworthy in this early publication, from a marine geological perspective, is the confrontation of different views on the progressive disappearance of calcareous shells on the seafloor, as depth increases beyond 5500 m in the Atlantic. The deeper seabed, both in the Atlantic and the Pacific, is composed of red clay, completely lacking any carbonate. This depth-dependency of carbonate content in the seafloor sediments had been observed along the first cross-section through the Atlantic, sailed by the *Challenger*, between Tenerife and St. Thomas (Antilles). Wyville Thomson considered an organic origin for the red clays: they would result from the accumulation of the tiny fractions of non-calcareous components (clays) contained in the shells of the foraminifera. When sinking to the depths, the calcareous shells dissolve, leaving the clay fraction as residue. John Murray, on the other hand, initially considered the weathering of

volcanic ash, accumulated in the deeper parts of the ocean, as the most plausible origin. Renard supports Wyville Thomson's hypothesis, arguing that the (pressure controlled) concentration of carbon dioxide at various depths is the major factor of dissolution of carbonate. Later, in the *Report on Deep-Sea Deposits*, the interpretations of Murray and Renard would converge and, building upon Sorby's early studies on the variable nature of the carbonate shells of marine organisms – some being composed of calcite while others of aragonite crystals – they would come to a formulation, quite close to our present insights in the 'carbonate compensation depth' (CCD), for both calcite and aragonite.

Renard concludes this review paper with some philosophical considerations. The introduction is of pure Lyell style:

En nous initiant aux phénomènes géologiques de la période que nous traversons, en suivant d'un oeil attentif la manifestation des forces qui agissent autour de nous, nous apprenons à relier les phénomènes anciens à leurs causes et à les interpréter. Cette méthode inductive, base la plus assurée de nos connaissances sur le passé de la terre, conduit le géologue à se demander quel fut le rôle des organismes inférieurs dans la formation des couches aux temps les plus primitifs de notre planète.

This being stated, Renard straightforwardly warns against a common abuse of such approach:

...la plupart des savants qui, dans ces derniers temps, ont traité le sujet, l'ont fait sous l'empire d'idées systématiques qui les portaient à exagérer singulièrement l'importance des dépôts fournis par les êtres inférieurs.

Referring to his earlier visit to Parker, where he had not been particularly impressed by the latter's thrill for Darwinism, Renard refutes Parker's prophecy that the detailed study of the Carboniferous limestone would soon prove the analogy with the calcareous sedimentation, presently accumulating on the seafloor. Renard observes, having scrutinized for several months thin sections of Carboniferous limestone,

... qu'aucun des échantillons étudiés ne peut être considéré, pour la totalité des éléments, comme dû aux organismes inférieurs.

The following lines confirm the early lack of empathy between Renard and Darwinism:

Or si nous voyons à peine dans ces couches l’empreinte des organismes inférieurs que réclame la théorie, quelle ne doit pas être notre réserve en face des assertions d’une école qui, sous prétexte de défendre la théorie des causes actuelles, substitue à l’observation des faits une conception qui se rattache par bien des points aux idées matérialistes sur l’apparition et l’évolution des organismes. En effet, si l’on part des principes transformistes...

The conclusions go *crescendo*:

De cette façon il leur semble plus aisé de rejeter loin d’eux l’idée d’une force créatrice, c’est le temps qui devient le grand facteur. La vie n’est plus qu’une combinaison particulière et fortuite des éléments matériels; elle s’est manifestée dans un passé lointain, débutant par des êtres qui se différenciaient à peine des substances minérales auxquelles elles devaient leur origine, et qui se modifiaient suivant les conditions du milieu où ils se trouvaient placés. Mais il est bien permis de se demander si, en substituant ainsi des idées systématiques aux conclusions qui découlent des faits, on reste fidèle au véritable esprit scientifique et à la marche rationnelle qui doit assurer le progrès.

The style of such *envoi* is not uncommon in geological debates of the 19th century, even prior to the polemics around Darwin’s ideas. But from about 1870 onwards, polemics in Belgium geared up on the background of an amplifying ideological polarization of society (34, 35). The first Vatican Council in 1870, which had defined the dogma of Papal Infallibility, had fueled an overall radicalization. Science would not escape. The ‘materialist’ interpretation which some German scientists, with Haeckel in the front line, soon had given to Darwin’s ideas, had further contributed to polemics (36).

Renard had published *Les organismes microscopiques de l’Océan et leur action en Géologie* in the *Revue des Questions scientifiques*, an outreach publication of the *Société scientifique de Bruxelles* founded in 1875 by Jesuits. The general objective of this Society was to promote full harmony between science and religion, however opposing materialism. Soon this

Society would count some 700 members, competing successfully with the more 'neutral' Academy of Sciences.

The shaping of Marine Geology: the '*Report on Deep-Sea Deposits*'

Renard's early publications and presentations had steadily gained approbation both in his own country and in Great Britain. He receives a letter from Edinburgh, dated September 5th, 1878:

My dear Sir,

During the scientific voyage of the "Challenger" many samples were procured illustrating the deposits now in process of formation at the bottom of the sea.

From the great attention you have paid to the structure of rocks and the many valuable contributions which you have made to knowledge on this and kindred subjects, I believe it would be important to science if you could make it consistent with your arrangements to examine these samples systematically and to contribute an account of them with suitable illustrations to the Official Report of the Expedition now in course of preparation. I will be greatly obliged if you kindly let me know if you can undertake this portion of the work.

I am my dear Sir yours with much respect
S. Wyville Thomson, Director of the Scientific Staff

Renard apparently was not fully unprepared, as the letter he would write to his director Edouard Dupont to solicit the authorization to respond positively to this invitation, is equally dated September 5th, 1878.

In this letter, Renard again developed the actualist argument which had been so successful a year earlier, however now referring to the Carboniferous limestone 'analogy' in such subtle terms, that he could not be caught in contradicting his recently published conclusions. The reason for his continuing allegiance to uniformitarian arguments in the letter to Dupont, notwithstanding his conviction of the lack of direct evidence in the Carboniferous, might have been tactical in quite a few aspects. It is in that

same year 1878 that the first French translation of Darwin's Part I of *The geology of the voyage of the Beagle – The structure and distribution of coral reefs* had appeared (37), stirring the interest of the French-speaking community on the Continent, not the least of Edouard Dupont. Three years later, Edouard Dupont presents at the Academy evidence for the coral reef origin of Belgian Devonian limestones, based on the analogy with those described in modern seas by Darwin. In his paper *Les îles coralliennes de Roly et de Philippeville* (38), he straightforwardly compares the Devonian "Atoll of Roly" with the Keeling Atoll, described in detail in Darwin's book³.

Covered by the agreement of the Minister of the Interior, Edouard Dupont indeed grants authorization to Renard to carry out these investigations, still recommending him to carefully avoid neglecting his administrative duties at the Museum. Renard would straightforwardly travel to Edinburgh to meet John Murray. While he primarily had been invited by Wyville Thomson to assist Murray in the examination and description of the *Challenger* collection of marine deposits, especially with reference to Renard's expertise in the mineralogical and petrographical aspects of the subject, it was soon arranged that the Report, to be published conjointly by Murray and Renard, would encompass all available samples of deep-sea deposits, whether collected by the *Challenger* or otherwise.

Back in Brussels, Renard writes a letter October 29th, 1878 to gratefully acknowledge the hospitality of Archibald Geikie, in those days director of the Scotland branch of the Geological Survey and first occupant of the Murchison Chair of Geology and Mineralogy at the University of Edinburgh. In an overview paper on *Recent Petrographical Literature* in *Nature* 1871, Geikie had noted that after the pioneering work of Sorby, the expertise in microscopical petrography had moved to the Continent:

English petrography does not exist; what we have in its stead is an indefinite obsolete grouping of rocks patched up with occasional borrowings from the Continent. ... Among the Continental petrographers who have led the way in the recent reform and extension of this branch of science, none can claim a more prominent place than Dr. Zirkel.

³ The coral reef origin of those Devonian limestones would be further popularized in the 1930's by Michel Thierry, founder of a museum of natural history in Ghent (39).

Clearly, there was a place at the *Challenger Office* for a zealous disciple of Zirkel. Renard had meanwhile demonstrated his full technical command of the discipline by publishing the same year an adaptation of Rosenbusch's design of a petrographical microscope, which he got built by Voigt and Hochgesang in Göttingen (40). With an enlargement of 1266x, he for the first time could provide evidence with this tool of fluid inclusions of carbon dioxide in ottrelite schists of the Ardennes.

This letter to Geikie would be the first of a long correspondence: 52 letters of Renard to Archibald Geikie, spanning the period from 1878 to 1893, are preserved in the Library of the University of Edinburgh. Up to 1891, Renard usually addresses Geikie as '*mon cher ami*' and from 1891 onwards reverently as '*Sir Archibald Geikie*', when the latter had received the honour of knighthood. These letters shed a new light on Alphonse-François Renard as a scientist and as a man.

The analytical work and the writing of the *Report on Deep-Sea Deposits* was a gigantic effort, spanning a full 13 years, from 1878 to 1891. Geikie states that this great monograph forms to the geologist perhaps the most valuable of all the massive *quarto* volumes of the *Challenger Reports* (12). This is a most laudatory statement, considering that some previous volumes had been signed by prestigious scientists such as Agassiz and Haeckel. Murray and Renard divided the deep-sea deposits mainly into two groups distinguished by the terms 'pelagic' and 'terrigenous'. The pelagic sediments encompass foraminiferal (*Globigerina*) ooze, pteropod ooze, diatom ooze, radiolarian ooze and pelagic clays, mainly the 'red clays'. Additional groups comprise volcanic sands or muds and coral sands or muds. This nomenclature for deep-sea sediments is still in use today. In addition, the Report and subsequent publications shed a new light on the role of cosmic dust which as a fine rain slowly accumulates on the sea floor, they revealed the low-temperature formation of zeolite crystals in the seabed sediments and they documented the distribution and mode of occurrence of manganese concretions, glauconitic deposits and phosphates. The study of phosphates dredged by the *Challenger* off the Cape Province would herald further studies on phosphates in the Basin of Mons by one of Renard's students, Jules Cornet (1865-1929), who would later gain fame by his role in the exploration of Katanga (Bia-Franqui expedition 1891-93).

One of the most spectacular outcomes is the first global map of deep-sea deposits. An early, large-size draft of this map is still kept at Ghent University. The final map, printed both in the *Report on Deep-Sea Deposits* and in a separate paper (6), results from the compilation of collections from more than 35 hydrographic, oceanographic and industrial cruises (mainly telegraph cable surveys).

The shaping of a geochemist: Renard in Vienna (1879-80)

Less than a year after the commencement of the cooperation with Edinburgh, Renard seeks to develop his geochemical skills, both for furthering the work on the geology of Belgium and for analyzing the sediments and rocks collected by the Challenger. On October 8th, 1879, he solicits the authorization of Edouard Dupont for spending some 5 to 6 months in Vienna which, according to German colleagues, would be the best choice for his purpose:

Cette ville, centre scientifique important pour les études géologiques, possède un établissement unique en son genre destiné aux recherches de chimie minérale; c'est le laboratoire de la Handelsakademie dirigé par M. E. Ludwig, l'un des plus célèbres analystes de l'époque. Enfin j'aurai l'occasion d'y être en rapport avec des savants tels que M. M. Tschermak et Hochstetter qui se sont occupés d'études analogues à celles que je suis chargé de faire.

With the support of a reference letter from Jean-Servais Stas (1813-1891), one of the leading chemists in Belgium in the mid-nineteenth century, and with a grant of the government of thousand franks, Renard would stay in Vienna from the end of October 1879 to June 1880. On his way back, he visits Ferdinand Zirkel in Leipzig, with whom he had maintained a close collaboration and friendship. Renard's stay in Vienna would become the start of numerous contacts with both Ludwig and Tschermak von Seysenegg (1836-1927), who had moved in 1877 from a position of director of the "Mineralogische Hof-Cabinet" to a full-time position as Professor for Mineralogy and Petrography at the University of Vienna. Many years later, Gustav Tschermak's son Erich, who had met Renard in the laboratory of his father in Vienna, would pursue studies in Botany at

Ghent University and enjoy the hospitality at Renard's home in Wetteren. In 1882, Constantin Klement, a chemist and student of Ludwig and Tschermak, would be recruited at the Natural History Museum in Brussels. When Renard moved to Ghent University in 1888, it is Klement who became his successor as curator in Brussels.

Renard's profound interest in the chemical and physical properties of rocks would find its expression in not less than 13 studies in experimental petrology, of which 3 dealing with the synthesis of rocks. In his conference '*La Reproduction Artificielle des Roches Volcaniques*' at The Royal Institution of Great Britain in London in 1888 (31), he expresses a view which in no term would differ from what a petrologist might state today:

La géologie, après avoir passé par les phases successive de l'observation et de l'analyse, est donc entrée dans celle de l'expérience et de la synthèse, où l'on s'efforce d'imiter la puissance créatrice de la nature, couronnant ainsi l'édifice scientifique par des procédés qui permettent d'entrevoir l'action des causes dont la connaissance est le but final des sciences physiques et naturelles.

Alphonse-François Renard in Scotland (1880-81)

Barely a few months after his return from Vienna, Renard would move in October 1880 to Scotland for some prolonged stays of several months at the *Challenger* office in Edinburgh, till early December 1881: the bulk of the work on the *Challenger* samples had begun. When Wyville Thomson had to resign from overseeing the 50 reports of the expedition in 1881, to pass away as a burnt-out man in March 1882, John Murray took over all editorial tasks for the reports, which no doubt amplified Renard's share of the work.

Once in Edinburgh, Renard would keep in touch with Archibald Geikie, even starting to translate in French the first edition of Geikie's *Textbook of Geology*. In his letters, he regularly acknowledges with sincere gratitude the hospitality offered at Geikie's home, where he enjoyed teaching the rudiments of French to his host's little daughter Lucy. Now and then, Geikie took Renard on field trips in Scotland, as far North as Cape Wrath, where the latter passed the night at the lighthouse-keeper's, sitting on a wooden chair with his arms and head resting on the table (12). While

crossing the North-Western Highlands, Geikie must have guided Renard to Inverpolly, where a heated debate had developed in previous years between Roderick Murchison, supported by Geikie, who saw a normal sequence of superimposed layers in Knockan Cliff, and Professor Nicol, soon supported by Lapworth, who identified amid the sequence a major low-angle fault, to be called the Moine thrust plane. The latter interpretation would imply an impressive horizontal displacement of a whole terrain. Such observation, adding to similar contemporaneous findings in more 'recent' mountain chains on the Continent, would herald the shift from 'verticalism' to 'horizontalism' in the models of deformation of the Earth's crust. The move to horizontalism would pave the way for the paradigm of plate tectonics in the later part of the 20th century. In a letter written June 2nd, 1881, during a brief stay on the Continent in between two stays in Edinburgh, Renard acknowledges the field trip to the Highlands as the 'crowning' of his stay. At a meeting of the Société de Géologie in Brussels, preceded by a meeting in Lille with Charles Barrois (1858-1939) and Jules Gosselet (1832-1916), Renard had enthusiastically reported about Murchison and Geikie's views on Knockan Cliff and claims general consent, except – to Renard's dismay – from Albert-Auguste de Lapparent (1839-1908) who had attended the Brussels meeting:

Il part d'une manière de voir qui me paraît tellement absolue, qu'elle ne peut être vraie. D'après lui les terrains anciens doivent être plus bouleversés qu'ils ne l'apparaissent, l'architecture des Highlands est trop simple, il faut compliquer sa structure par des failles... Bref, il n'y a souvent rien à répondre à un charmeur comme de Lapparent, je lui ai dit seulement d'y aller voir et que ces questions ne se discutaient pas au coin d'une table. Je lui ai rappelé à ce sujet le mot de Quenstedt: *Für einem Geologe sind oft gute Beine nützlicher als einen guter Kopf.*

As a matter of fact, de Lapparent would turn out to be right, and Geikie would soon revise his opinion after having commissioned an impartial investigation, which in 1884 reported in favour of the interpretation of Nicol and Lapworth. This letter however interestingly shows how Renard stood at least as an interested witness of some of the major geological debates of his time, besides playing an active role in some of them. Moreover, it illustrates the style of many of Renard's writings to Geikie, half serious, half jest, and not always deprived of some gentle touch of flattery.

The debate on St. Paul's Rocks

In the same letter of June 2nd, 1881, Renard acknowledges Geikie's advice on a manuscript dealing with rock samples, collected by the *Challenger* on St. Paul's Rocks, a cluster of rocks midway Brasil and Africa, close to the equator:

... pour vous remercier spécialement de l'excessive bonté que vous m'aviez témoignée en remaniant, avec le talent qui vous distingue, mon pauvre manuscrit de St. Paul.

Renard must have received samples of St. Paul's Rocks while in Edinburgh in fall 1878, considering that he had published a first paper in March 1879 in the *Neues Jahrbuch für Mineralogie*: "*Peridotit von der St. Paul's-Insel im Atlantischen Ocean*" (41).

These small islands had already been visited and sampled by Darwin, who had postulated that the rocks, containing thin veins of serpentine, formed an exception to the general volcanic nature of oceanic islands. The St. Paul's Rocks had been regarded by many authors as the last remnants of a vast drowned continent, an Atlantis, or at least the remnant of continental masses which had supported faunal migration between the African and American continents⁴. The peridotites identified by Renard are mantle rocks nearly fully composed of olivine. In the monograph published in the *Annales de la Société belge de microscopie*, 1882 (43), Renard had related these rocks to a metamorphic complex, in French petrographical terms of the 19th century commonly referred to as "schistes cristallins". This paper would give rise to comments of Archibald Geikie in *Nature* (1882) and of the American petrologist Marshman Edward Wadsworth (1847-1921) in *Science* (1883), both claiming a volcanic origin of St. Paul's Rocks. Renard diplomatically eludes Geikie's comments but writes with eloquence in a 12 pages long reply in the *Annales de la Société belge de microscopie* (44) a delightful and detailed refutation of Wadsworth's criticisms, in particular those suggesting that Renard would have claimed "...that these rocks may be *metamorphic sedimentary rocks*, and therefore, according to him, true

⁴ The hypothesis of a land bridge between Africa and Brasil through St. Paul's Rocks would persist till the 1930's, in particular in papers of Bailey Willis (42).

schists”. Those were the times where a simple semantic confusion between French and Anglo-Saxon writers could earn a citation in *Science*.

The papers on St. Paul’s Rocks would be the first of a whole list of publications on the petrology of the islands, visited by the *Challenger*: Fernando-Noronha (1882) (45), on which Renard further elaborates in his correspondence with Geikie in 1883, the Falklands (1885) (46), Tristan da Cunha (1885) (47), Juan Fernandez (1885) (48), the Camiguin volcano (1885) (49) and the Cebu and Malanipa Islands in the Philippines (1886) (50), the active Ternate volcano on the Mollucca Islands (1886) (51), the Kantuvu Island in the Fidji Archipelago (1886) (52), the Goonong-Api on Banda Islands (1886) (53), Marion Island (1886) (54), Kerguelen (1886) (55), Heard Island (1886) (56), the Inaccessible and Nightingale Islands (1887) in the Tristan da Cunha Group (57), Asuncion (1887) (58), Pico de Teyde on Tenerife (1887) (59), Cabo Verde (1888) (60). In addition, Renard would report on the composition of the Krakatau ashes collected in Batavia, barely a few months after the eruption of August 27th, 1883 (61).

This clearly demonstrates that Renard did not ‘confine’ himself to the already gigantic data set from the deep-sea deposits, but that he also ventured to explore and understand the magmatic processes from the oceanic realm. As we know today, the studied islands are the surface expression of processes of volcanism related to seafloor spreading, plate subduction and mantle plume activity, as well as metamorphic processes associated to fracture zones, all intimately linked to the grand paradigm of mantle dynamics and plate tectonics which would take another 80 years to move to the forefront of Geosciences. In contrast to the team work of the ‘Report on Deep-Sea Deposits’, Renard’s description of the oceanic islands was largely a solitary exercise.

The shaping of a professor: Renard at Ghent University

The eighties had not only been tremendously productive years for Renard, but also very turbulent ones. It also looks as if he blurred traces in the beginning of the eighties. While his move to Vienna from October 1879 to June 1880 is clearly documented in the archives of the Royal Museum of Natural History, the Catalogue of the Belgian Province of the Society of Jesus records that he resumed studies in Philosophy at the Catholic Univer-

sity of Leuven in 1879-80, even being 'Bidel' or spokesman of his class to the Rector. In 1880, his name would definitively disappear from the Catalogue. Shortly before leaving to Scotland in fall 1880, he would have travelled to Florence to meet the General of the Society of Jesus. He had not yet taken the final step that would have completed his attachment to that Order, and took the liberty he still had to go no farther. His departure from the Society of Jesus, confirmed to him in 1883, did not imply he would leave the Church. He remained for many years one of the secular clergy. In 1881, he moved with his mother to the elegant avenue Brugmann in Ukkel (Brussels).

In December 1882, Renard is elected corresponding member of the Academy of Sciences. Having been elected a Foreign Correspondent of the Geological Society of London in 1880, immediately after the commencement of the publication of his contributions to the *Challenger* studies, he becomes Foreign Member in 1884. He also had been elected Honorary fellow of the Royal Society of Edinburgh. In a long letter to Geikie dated January 1885, he reports the increased difficulties he experiences at the Museum, to the point that he looks out for an alternative position.

“J’ai été appelé il y a quelques jours à Louvain où le Recteur m’a offert de prendre de nouveau la minéralogie et la lithologie avec la chimie minérale. Les relations que j’ai avec de la Vallée ne me permettent pas d’accepter et je n’y pense plus. A l’Université de Gand, un professeur de Géologie illustre inconnu qui n’a jamais écrit une ligne sur cette science⁵ doit se retirer pour cause d’âge. Cette nomination est une décision qui ne dépend pas du conseil académique ni du Recteur mais des Ministres. Je voudrais aller à Gand, mais je trouve M. Mourlon sur mon chemin et il a des soutiens qui sont puissants, son beau-frère étant Ministre Chef du Cabinet. Je ne puis m’appuyer que sur mes connaissances scientifiques pour demander cette position, qui me fixerait d’une manière conforme à mes aptitudes, et à mon goût. Dans ces circonstances il me serait fortement utile de me voir appuyé par un moyen sur lequel mon attention a été attirée lors de mon dernier séjour à Londres. On m’a parlé des distinctions qu’accorde la Société Géologique tous les ans en mars ou en février. J’ai appris qu’il y a 4 ans M. Philips m’avait présenté au Conseil comme candidat pour le prix de Bigsby, on lui a répondu que j’appartenais à une communauté religieuse et que les

⁵ Renard refers to Maximilien Louis Gustave Dugniolle (1822-1903).

fonds ne seraient pas donnés à moi. Laissant à d'autres le soin d'évaluer mes titres, je prends la liberté de vous demander confidentiellement si dans les circonstances actuelles, vous ne voyez pas le moyen de faire renaître ma candidature et de la faire appuyer. ... Je ne demande pas la distinction Bigsby, mais n'importe quel petit grant que ce soit, il ne s'agit pas d'une affaire d'argent, je l'abandonnerais volontier aux pauvres; mais tout ce qui me viendrait de la Société Géologique de Londres serait un fort appui moral pour obtenir la position que je demande."

Renard would receive the Bigsby Medal a few months later, in 1885. Further honours would follow. On the 13th of June 1888, at the VIIIth Centenary celebration of the University of Bologna in the Archiginnasio galleries – *Festa dell'intelligenza* – a honorary degree was conferred upon some of the most illustrious scholars, scientists, jurists and politicians of the time: *la laurea d'onore* (62). Renard received the golden ring with seal and the silver commemoration plate, among other laureates such as Alexander Agassiz, Louis Pasteur, Herman Helmholtz, Ernest Renan, Marcellin Berthelot, Robert Bunsen, William Thomson (Lord Kelvin), Ferdinand de Lesseps, Valentin Boussinesq, Charles Hermite, Leopold Kronecker, Thomas Huxley, Robert Koch, and many others. A few months later, the 30th of August 1888, he could take the chair of geology and mineralogy at Ghent University.

If the subtle 'fishing' for the Bigsby medal, revealed by his correspondence with Geikie, sounds amusing and quite human, one should not overlook that Renard had not acquired any formal academic degree to qualify for a professorate, and hence was totally dependent on his scientific productivity and on any explicit peer recognition for credentials. The passport to the position of curator at the Museum had been the memoir crowned by the Academy, which is beyond doubt of the level of a PhD, but it was a co-authored work, what still nowadays would be *avant-garde* in terms of academic qualification. That it would take a full 3 years to obtain the earnestly desired position at Ghent University, as appears from his correspondence with Geikie, is under such circumstances not utterly surprising. We speculate that the prestigious *laurea d'onore* of Bologna might significantly have contributed to the final move of the Ministry. Further honours would be conferred upon him in later years, for instance as invited guest of

the Tercentenary Celebration of Trinity College, Dublin, in July 1892 (63). In 1901, he figures on the list of the 20 Honorary Members of the Mineralogical Society, among founder fathers of this discipline such as Dana, Fouqué, Lacroix, Lévy, Ludwig, Rosenbusch, Tschermak and Zirkel.

The tensions at the Museum and the attitude of his close colleague Michel Murlon (1845-1915), evoked by Renard in his letter to Geikie of January 29th, 1883, were probably not unrelated to the turbulent early days of the official geological map of Belgium and the crisis which eventually led to the grand schism in Belgian geology and the creation of a second geological society, next to the *Société géologique de Belgique* founded in Liège: the *Société belge de Géologie, de Paléontologie et d'Hydrologie* was founded in Brussels in 1887 (64, 65). Renard became a founding member of the new society.

The *début* of Alphonse-François Renard as professor at Ghent University would not be an easy ride either. The initial hostility of the – not excessively clerically-minded – students of Ghent University towards ‘l’abbé Renard’ would however soon turn into appreciation and respect, not the least by the quality of his lectures and the intensity of the field work he introduced, building upon his in-depth knowledge of the geology of Belgium (10). A hand-written copy of part of his course notes is still kept in the Library of Ghent University. While still at the Museum, Renard had demonstrated his “gute Beine” by organizing excursions in the Ardennes with day trips up to 30km (18): the way to win the hearts and minds of students in geology. It is at Ghent University that Renard would recover the time, freedom and serenity to complete his *magnum opus* with John Murray – the *Report on Deep-Sea Deposits* (1891). In parallel, he would not neglect the preparation of lasting scholarly works, like *Les Fondateurs de la Minéralogie* in 1896 (66) and the *Notions de Minéralogie* in 1900, a book of 374 pages and 732 intercalated figures, co-authored by his collaborator F. Stöber (67).

The shaping of a union: Alphonse-François and Henriette

The nomination of Alphonse-François Renard at Ghent University would compel him to move from Ukkel. Since 1882, he had got closely befriended with his neighbours, the family Van Gobbelschroy. Mr. Van Gobbelschroy

had clear sympathies for the French revolution of '89. Henriette, his daughter, was aged 16 when she first met Renard. In a 'souvenir' paper, she recalls sweet moments (14):

A ce foyer, et tandis que la jeune fille accumulait laborieusement ses travaux d'école, l'abbé Renard venait s'asseoir volontiers. Les discussions philosophiques, ardentes mais courtoises, faisaient le fond de la conversation et, maintes fois, le regard interrogateur de la jeune fille se leva sur ce prêtre à l'esprit lumineux... Six années se sont écoulées: dans la famille amie où, si souvent, l'abbé Renard s'est senti accueillir avec une chaude sympathie malgré la divergence d'opinions, le nouveau professeur de géologie à l'Université de Gand vient faire ses adieux. La toute jeune fille d'autrefois a vingt-et-un ans et c'est dans son coeur, soudain, un déchirement qui fait la lumière: cet ami si lointain dans sa robe de deuil, ce pauvre savant à jamais solitaire et qui en souffre, elle le sent avec son intuition de femme, elle l'aime depuis longtemps, depuis leur première rencontre!...

Ghent – the 'Manchester of the Continent' – still featured in 1888 a medieval texture, heavily overprinted by the industrial revolution. The choice in 1881 of the location of the new building for the Institute of Sciences, to be built by architect A. Pauli to open its doors in 1890, had been primarily guided by concerns of urban sanitation. The selected 'Batavia' sector of the *cit  ouvri re* where Pierre De Geyter was born (1848), composer of the hymn 'Internationale' (1888), has been immortalized by prints of Jules De Bruycker (1870-1945). The city itself, with its network of polluted canals and rivers, was barely habitable. Intellectuals and artists had already exiled to St. Martens-Latem. Renard had been acquainted for years with Prof. Emile Van Ermengem (1851-1932) of Ghent University, who has gained fame for his studies of cholera, typhus and botulism. He had equally stayed in Edinburgh, Vienna and London, in addition to Koch's laboratory in Berlin, and he shared Renard's passion for microscopy. When Renard was president of the *Soci t  belge de Microscopie*, Van Ermengem was adjunct-secretary. Van Rentergem lived in a nice villa with a large garden and pond in Wetteren, and we speculate that it was him who advised Renard to settle in this village, conveniently connected to Ghent by the railway. The village of Wetteren of the second half of the 19th century has been evoked in many novels of Van

Ermengem's son, better known as writer under the pseudonym of Franz Hellens⁶, whose first collection of poems, dedicated to Ghent and illustrated by De Bruycker, sounds eloquent: *En ville morte*.

Renard's key moments of intellectual and ideological crisis have been vividly depicted by Henriette Van Gobbelschroy (14):

Alphonse Renard est à Wetteren, dans une charmante vieille maison. En dehors de ses cours, il vit dans une solitude studieuse, "tout à ses cailloux", comme il le dit avec un mélancolique sourire. Cependant, l'abbé Renard revoit de loin en loin M. Van Gobbelschroy et sa famille... Un jour, au cours d'une visite, l'abbé Renard s'est laissé emporter par son enthousiasme de savant, en exposant devant ses amis la théorie du transformisme: son langage a eu une telle netteté d'inébranlable conviction que Mlle Van Gobbelschroy fait cette involontaire réflexion: "Au point où vous êtes arrivé, vous ne pouvez plus admettre la Révélation!" L'homme de science et de raison s'est dévoilé à l'insu du prêtre, mais le prêtre, anxieusement et comme si un attouchement cruel venait d'effleurer une plaie de son âme, répond à la jeune fille: "Si cela était, je n'aurais plus qu'à déposer ma soutane!" La phrase est tombée dans le silence profond de la salle de famille. Et se fut par une inoubliable matinée d'avril que M. Renard dit à Mlle Van Gobbelschroy ces inoubliables paroles: "Oui, il y a longtemps qu'en moi la foi du prêtre est morte! J'avais quarante ans quand je l'ai sentie mourir. Mais ma mère était là; pour elle j'ai fait taire ma raison suppliciée."

On October 21st, 1898, Renard's mother passes away. The first signs of illness show up and Renard undergoes two surgeries for cancer of the tongue in 1899. He leaves the Church early 1901. On March 21st, 1901, he marries Henriette Van Gobbelschroy in London. Paying a visit to Westminster Abbey, he points to his wife the tomb of Lyell: *là repose celui à qui je dois mon affranchissement*.

⁶ The Wetteren of Renard's time is depicted in Franz Hellens' books in the author's typically contrasting styles, ranging from early youth memories (*Frédéric*) (68) to social drama in the Wetteren of the industrial revolution (*Les marées de l'Escaut*) (69).

Renard and *Les Amis Philantropes*

In 1902, two years after having resigned from the *Société scientifique de Bruxelles*, of which he had been a member for 25 years, Renard is embraced by *Les Amis Philantropes*, a prominent lodge in the history of Belgian freemasonry. In 1834, Théodore Verhaegen, *Vénérable Maître* of *Les Amis Philantropes*, had called for the creation of the *Université Libre de Bruxelles*. The ULB would be born in 1837. Though *Les Amis Philantropes* can be regarded as its cradle, the ULB strived from its very first years towards a national profile and in critical moments, it clearly confirmed its autonomy (70). The original refusal of dogma in scientific matters would soon lead to the broadest concept of *libre examen*, comprising the generalized expression of contradictory opinions. This would indirectly contribute to a crisis in 1894, when the French geographer Elisée Reclus (1830-1905), who just had been appointed as chairholder of comparative geography at ULB, saw his lectures suspended for reasons of alleged links with French anarchists. This was a surprising decision of ULB, as the least one could say is that, throughout his life, Reclus had made no secret of his vibrant sense of anarchy, only rivaled by his prolific scientific productivity. Progressive brothers of the *Amis Philantropes* then decided to create a competing and resolutely modern university – *l'Université Nouvelle de Bruxelles* – a move that eventually resulted in a schism in *Les Amis Philantropes* itself, the more traditionalist members creating the *Amis Philantropes n°2*. This story around Elisée Reclus and geography is maybe not irrelevant. In 1898, Renard had made a remarked plea for strengthening physical geography – to include a. o. oceanography – in academic curricula in Belgium, documenting extensively examples in Vienna (Penck), Prague and Germany (71).

The shaping of Belgium's Antarctic epos: Renard and the *Belgica*

Shortly after the publication of Murray and Renard's map of the deep-sea sediments (1894), both Pelseneer and Renard were contacted by Adrien de Gerlache de Gomery (1866-1934), a young naval officer who fostered plans for a Belgian Antarctic expedition. Adrien de Gerlache had previ-

ously taken contacts with Nordenskjöld for a common enterprise, but in vain. The enthusiastic support of both Pelseneer and Renard would be decisive (72). Renard's reaction was clear:

Je tiens à vous dire que je suis prêt à seconder très sérieusement vos démarches. Je suis désireux de les voir aboutir et je vous promets de vous donner l'appui que je puis vous prêter.

Fund raising became successful in 1895, with a significant support from the scientific societies and Ernest Solvay. In 1896, the Norwegian *Patria* would be christened *Belgica* in Sandefjord. She would sail from Ostend to the Antarctic in August 1897, to return in November 1899 to Antwerp, after completion of the first Antarctic overwintering. In 1901, Arctowski and Renard published the *Notice préliminaire sur les Sédiments Marins recueillis par l'Expédition de la "Belgica"* (73), containing a bathymetric map of Drake Passage from the soundings of the research vessel. Renard would also start with the preparation of the petrographical analysis of the rock samples collected by the *Belgica*, but he could not proceed, due to his illness. After Renard's death, some 700 thin sections were handed over by Arctowski to A. Pelikan and D. Sístek in Prague, who would publish their analyses in the Scientific Reports of the Commission of the *Belgica* in 1909. Chemical analyses were carried out at Ludwig's laboratory in Vienna. One of the most impressive capes of the Antarctic continent, in Gerlache Strait, has been named *Cape Renard*. Wildlife artist and explorer Keith Shackleton caught in a beautiful painting the summer light, the snow and ice and the play of the Antarctic petrels at the foot of Cape Renard.

Epilogue

This paper has focused on Alphonse-François Renard's contribution to the rise of marine geology, with due attention for the human dimension. It may be regarded as a curiosity-driven quest of the author to the sources of the *Report on Deep-Sea Deposits*. If we gladly pay tribute to Luigi Ferdinando Marsili (1658-1730) as the early 18th century pioneer of ocean science who featured a genuine interest for geology (74), it is generally recognized that it is in the achievements of the cruise of *H.M.S. Challenger* that we may see the dawn of modern ocean science, and in particular of marine geology.

One indeed might reasonably state that marine geology could only start as a scientific discipline when team work was invented. Any major marine geological venture builds upon the combination of entrepreneurship, technology, seamanship, scientific excellence and editorial skills. Sir Wyville Thomson, John Murray and Alphonse-François Renard deserve to move into the history of marine geology jointly, as an exceptional team: Thomson as visionary entrepreneur and first manager, Murray as brilliant scientific sailor and persevering editor, Renard as indefatigable analyst and erudite writer.

As we realize today from Renard's correspondence, we maybe should not overlook in this story Sir Archibald Geikie, as an influential political ally, efficient scout and coach, who from the sideline catalyzed contacts between the Scottish scientists and targeted experts from the Continent. Renard had manifested himself at the right moment, as the right man on the right place. He mastered the German language and his command in microscopical petrography, a legacy of Zirkel, was exactly what Geikie and Thomson had been keen to get into the project. In the exploitation of the data on deep-sea sediments from the *Challenger*, Brussels and Ghent would thus take between 1878 and 1891 a pivotal position between the poles of Scottish entrepreneurship in marine science and German analytical power in petrography.

Apparently fluent in French, Geikie would intelligently second Renard morally through years of heavy workload. While no doubt primarily driven by concerns for the success of the project, Geikie still conveyed to Renard tokens of sincere friendship. Between the lines of Renard's letters, one reads an inspiring enjoyment of his regular stays at the Geikie's, among the kids Lucy, Rodrick and Mady. Many years later, Renard's words to his physicians, when he got informed of the disease which would become fatal, were anything but equivocal: *Je dois vivre, je viens de fonder une famille!* (14).

Along this quest, we indeed had the opportunity to get access to some sources and letters, largely unexplored and unexploited yet. They gave us some insight in Renard's soul, at some decisive moments, in decisive issues. These sources still do contain a wealth of information, which may help to better position Renard as a geologist amid the leading geological minds and circles of his time, and as a man. There are many more pages to read and write, not only about the significance of Renard's analyses of

deep-sea sediments, but also about Renard's insights in the geology of Belgium, his vision on experimental petrography and on Earth Science in general. As to Renard's philosophical attitude and its evolution in the turbulent second half of the 19th century, elements of it have been reported in quite a few of the cited biographies, but new insights may soon arise from ongoing studies in human sciences.

Already in pains of intestine cancer and with the ultimate deadline in sight, Renard remained a scientist, a thinker and an indefatigable worker. He finished in 1902 the translation of Darwin's geological observations on the volcanic islands, visited by the *Beagle* (7). The last lines of the prologue are eloquent:

J'estime qu'il est bon de rappeler aux consciences ces héros de la vérité qui n'eurent d'autres armes que leur intelligence libérée des préjugés, leur raison éclairée, leur travail opiniâtre et calme et qui surent remplir au prix d'amertumes sans nombre la si difficile tâche d'avoir fait accomplir à la pensée humaine un pas en avant. Entre eux, Darwin est des premiers.

Among those who assisted Alphonse-François Renard in his last moments, we note Adrien de Gerlache and Ernest Solvay. His funeral was attended by the Rector of Ghent University, Prof. Vandermensbrugghe, by the Mayor of Ghent, Emile Braun, by Lecointe and Arctowski, members of the *Belgica* expedition, by Elisée Reclus and many other dignitaries. Renard's tombstone in the cemetery of Ixelles (Elsene), on which had been engraved the words *Veritas eum liberavit*, has disappeared. The Belgian sculptor Constantin Meunier (1831-1905) has been buried next to Renard's tomb, two years later.

Ixelles has commemorated Renard by naming a street after him, and the ULB organized for years a cycle of *Conférences Alphonse Renard*. About 100 years after Renard's nomination as professor at Ghent University, the 'Renard Centre of Marine Geology' (RCMG) was founded at this institution (1987). When RCMG discovered in 2002 two spectacular ridges speckled with cold-water coral mounds and dwarfed by giant mud volcanoes off Morocco (75), these ridges were respectively named in honour of Wladimir Ivanovich Vernadsky (1863-1945) and Alphonse-François Renard, each in his domain a pioneer in the unveiling of the role of life in geology.

A statue made by sculptor A. De Tombay stands between the Jardin du Roi and the Elsenne lakes. Under some angle and illumination, Renard's face offers a boyish look. De Tombay's artwork is heavily weathered and invaded by moss, the stone decaying grain by grain, as if Renard wished to convey with a twinkle an ultimate demonstration of Lyell's laws.

Alphonse-François Renard's *envoi* at the London conference of 1888, borrowed from Leibniz, comes to our mind: *car la nature n'est qu'un art en plus grand*.

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References

- [1] Sarton, G. (1919). La Synthèse Géologique de 1775 à 1918. *ISIS*, 6, II, 367-394
- [2] Suess, Ed. (1897). *La Face de la Terre (Das Antlitz der Erde)*. Translation under editorship of Emm. De Margerie, Armand Colin, Paris, 1724 + 258 pp.
- [3] Thomson (C.W.) (1873). *The Depths of the Sea: an account of the general results of the dredging cruises of H.M.SS. 'Porcupine' and 'Lighthouse' during the summers of 1868, 1869 and 1870, under the scientific direction of Dr. Carpenter, F.R.S. J. Gwyn Jeffreys, F.R.S., and Dr. Wyville Thomson, F.R.S.*
- [4] Murray, J. & Renard, A.-F. (1891). Report on Deep-Sea Deposits. Report on the Scientific Results of the Voyage of H.M.S. Challenger during the years 1873-76, 583 pp.
- [5] Murray, J. & Renard, A.-F. (1884). On the nomenclature, origin and distribution of deep-sea deposits, *Proc. of the Royal Society of Edinburgh*, 12, 495-521
- [6] Murray, J. & Renard, A.-F. (1894). *Carte des Sédiments de Mer Profonde avec Notice Explicative*. Bruxelles, Soc. Belge de Librairie, 45 pp., map.
- [7] Darwin, C. (1902). *Observations géologiques sur les îles volcaniques explorées par l'expédition du "Beagle" et notes sur la géologie de l'Australie et du Cap de Bonne-Espérance*. Translation of the 3rd edition by A.-F. Renard. Schleicher, Paris.

- [8] Darwin, C. (1844). Geological observations on the volcanic islands visited during the voyage of H.M.S. Beagle. Part 2 of The geology of the voyage of the Beagle. London.
- [9] Seibold, E. & Berger, W.H. (1982). The Sea Floor. Springer-Verlag, Berlin, 288 pp.
- [10] Kaiser, G. (1893). A.-F. Renard. *in* Broerman E., Célébrités Nationales. Dero Frères Editeurs, Anvers.
- [11] Geikie, A. (1903). Alphonse-François Renard. Obituary. The Geological Magazine, London, Decade IV, Vol. X, 525-527
- [12] Geikie, A. (1904). Alphonse-François Renard. Anniversary Address. Quarterly Journal of the Geological Society of London, 60, lix-lxiii
- [13] Fiévez, C. (1904). A.-F. Renard. Eloge fait à la Société Belge d'Astronomie. Bruxelles, 8 pp.
- [14] Renard, H. (1907). Alphonse Renard. Souvenirs. Bruxelles, 15 pp.
- [15] Mansion, P. (1913). A.-F. Renard. Liber Memorialis. Notices biographiques. Tome II. Gand, 291-301.
- [16] Buttgenbach, H. (1953). Notice sur Alphonse-François Renard, membre de l'Académie, Ann. de l'Académie Royale de Belgique, 387-413.
- [17] Roekeloos, A. (1976). La vie mouvementée d'un savant: Alphonse-François Renard. Annales, Cercle historique et archéologique de Renaix et du Ténement d'Inde, XXV, 163-189
- [18] Van Tassel, R. (1978). A.-F. Renard, Conservateur (1877-1888) au Musée royal d'histoire naturelle de Belgique. Annales, Cercle historique et archéologique de Renaix et du Ténement d'Inde, XXVII, 13-39
- [19] Houvenaghel, G.T. (1980). Belgium and the Early Development of Modern Oceanography, Including a Note on A.-F. Renard. *in* Oceanography: The Past. Proc. Third Int. Congress on the History of Oceanography, Woods Hole, Mass. Springer-Verlag New York, 667-681
- [20] Houvenaghel, G.T. (2002). Contribution de la Belgique au développement de l'Océanographie au XIXe siècle: rôle du Professeur Alphonse Renard (Renaix 1842 – Ixelles 1903). Sixième Congrès de l'Ass. des Cercles Francophones d'Histoire et d'Archéologie de Belgique, Mons, Actes, Tome III, 571-580
- [21] Walschot, L. (1992). A.-F. Renard. Universiteit Gent, Geologisch Museum, 6 pp.
- [22] Anon. (1903). Monsieur A.-F. Renard. Almanach de l'Université de Gand. Société générale des étudiants libéraux, Gand, 9-14.
- [23] Anon. (1904). Alphonse-François Renard. Sa vie et ses oeuvres. Comité d'Emancipation Intellectuelle. Publication périodique n° 4. Anvers, 35 pp.
- [24] Hopmann, M., Frechen, J. & Knetsch, G. (1959). Die vulkanische Eifel. W. Stollfuss Verlag, Bonn, 143 pp.
- [25] Bogler, Th. (1963). Benedikt und Ignatius. Maria Laach als Collegium maximum der Gesellschaft Jesu 1863-1872-1892, Maria Laach.
- [26] Schminke, H.-U. (2009). Vulkane der Eifel. Spektrum Akad. Verlag Heidelberg, 160 pp.
- [27] de la Vallée Poussin, Ch. & Renard, A.-F. (1876). Mémoire sur les caractères minéralogiques et stratigraphiques des roches dites plutoniennes de la Belgique et de

l'Ardenne française. Mémoires couronnés et mémoires des savants étrangers, Académie Royale de Belgique, 264 pp.

- [28] Sorby, H.C. (1858). On the microscopical structure of crystals, indicating the origin of minerals and rocks. *Geol. Soc. London Quat. Journal*, 14, (1), 453-500
- [29] Touret, J. (2009). De la Pétrographie à la Pétrologie. In Gaudant J. (éd.) *L'essor de la géologie française. Essais*, Presses des Mines, Paris, 171-199.
- [30] Renard, A.-F. (1876). Some results of a Microscopical Study of the Belgian Plutonic Rocks. *The Monthly Microscopical Journal*, May 1876, 212-218.
- [31] Renard, A.-F. (1888). La Reproduction Artificielle des Roches Volcaniques. Royal Institution of Great Britain, Weekly Evening Meeting, May 18, 1888, 16 pp.
- [32] Renard, A.-F. (1877). On the Mineralogical Composition and the Microscopical Structure of the Belgian Whetstones. *Transactions of the Royal Microscopical Society*, 269-281
- [33] Renard, A.-F. (1878) Les organismes microscopiques de l'Océan et leur action en Géologie. *Extrait de la Revue des Questions scientifiques*, 42 pp.
- [34] Vanpaemel, G. (2001). De darwinistische revolutie. in *Geschiedenis van de wetenschappen in België 1815-2000. La Renaissance du Livre, DEXIA*, Vol. 1, 257-268.
- [35] De Bont, R. (2008). Darwins kleinkinderen. *De evolutietheorie in België 1865-1945. Vantilt, Nijmegen*, 523 pp.
- [36] Dampier, W. (1951). *Histoire de la Science et de ses rapports avec la Philosophie et la Religion*. Transl. from Engl. by R. Sudre. Bibliothèque Scientifique, Payot, Paris, 601 pp.
- [37] Darwin, C. (1878). Les récifs de corail, leur structure et leur distribution. Transl. from Engl. by M.L. Cosserat. Paris, Librairie Germer Baillière et Cie, 347 pp.
- [38] Dupont, E. (1881). Les îles coralliennes de Roly et de Philippeville. *Bull. de l'Acad. roy. de Belg.*, 3e série, II, 89-160.
- [39] Thiery, M. (1932). *De geschiedenis van een koraaleiland (Proeve van een natuurwetenschappelijk Sprookje)*. Drukkerij Hoste, Gent, 67 pp.
- [40] Renard, A.-F. (1878). Note sur un microscope destiné aux recherches minéralogiques. *Extrait des Bulletins de la Société belge de microscopie*, tome IV, 16 pp.
- [41] Renard, A.-F. (1879). Peridotit von der St. Paul's-Insel im Atlantischen Ocean. *Separat-Abdruck aus dem Neuen Jahrbuch für Mineralogie etc.*, 5 pp.
- [42] Willis, B. (1932). Isthmian links. *Bull. of the Geol. Soc. of America*, 43, 917-952
- [43] Renard, A.-F. (1882). Description lithologique des récifs de St.-Paul. *Extrait des Annales de la Société belge de Microscopie*. Bruxelles, Lib. Manceaux, 53 pp.
- [44] Renard, A.-F. (1883). A propos des roches de St.-Paul. *Annales de la Société belge de microscopie*, 165-178.
- [45] Renard, A.-F. (1882). Notice sur les roches de l'île de Fernando Noronha, recueillies pendant l'expédition du Challenger. *Extrait des Bulletins de l'Acad. roy. de Belgique*, 3e série, tome III, 4, 12 pp.
- [46] Renard, A.-F. (1885). Notice sur les roches des "fleuves de pierre" aux Iles Falkland. *Extrait des Bulletins de l'Acad. roy. de Belgique*, 3e série, tome X, 9-10, 10 pp.

- [47] Renard, A.-F. (1885). Note sur la géologie du groupe d'îles de Tristan da Cunha. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome IX, 5, 15 pp.
- [48] Renard, A.-F. (1885). Notice sur les roches de l'île de Juan Fernandez. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome X, 11, 8 pp.
- [49] Renard, A.-F. (1885). Le volcan de Camiguin aux Iles Philippines. Extrait des Bulletins de l'Acad. Roy. de Belgique, 3e série, tome X, 12, 21 pp.
- [50] Renard, A.-F. (1886). Notice sur quelques roches des Iles Cebu et Malanipa (Philippines). Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XI, 4, 11 pp.
- [51] Renard, A.-F. (1886). Notice sur les roches du volcan de Ternate. Extrait des Bulletins de l'Acad. Roy. de Belgique, 3e série, tome XI, 2, 8 pp.
- [52] Renard, A.-F. (1886). Notice sur les roches de l'île de Kantavu (Archipel des Fiji). Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XI, 3, 12 pp.
- [53] Renard, A.-F. (1886). Le volcan de Goonong-Api aux Iles Banda. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XI, 2, 8 pp.
- [54] Renard, A.-F. (1886). Notice sur les roches de l'île Marion. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XII, 8, 8 pp.
- [55] Renard, A.-F. (1886). Notice sur la géologie de l'île de Kerguelen. Bulletin du Musée Royal d'Histoire Naturelle de Belgique, tome VI, 223-269
- [56] Renard, A.-F. (1886). Notice sur les roches de l'île Heard. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XII, 8, 14 pp.
- [57] Renard, A.-F. (1887). Notice sur les roches des Iles Inaccessible et Nightingale (groupe de Tristan da Cunha). Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XII, 8, 28 pp.
- [58] Renard, A.-F. (1887). Notice sur les roches de l'île de l'Ascension. Bulletin du Musée Royal d'Histoire Naturelle de Belgique, tome V, 5-58.
- [59] Renard, A.-F. (1888). Note sur les roches du Ppic de Teyde (Ténériffe). Bulletin de la Société Belge de Géologie, Paléontologie et d'Hydrologie, II, 67-81.
- [60] Renard, A.-F. (1888). Notice sur quelques roches des Iles du Cap-Vert. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome XV, 4, 24 pp.
- [61] Renard, A.-F. (1883). Les cendres volcaniques tombées à Batavia le 27 août 1883. Extrait des Bulletins de l'Acad. roy. de Belgique, 3e série, tome VI, 11, 14 pp.
- [62] Bortolotti, M. (1988). Gli allori del 1888: diario della "Festa dell'intelligenza". Saecularia Nona, Università di Bologna 1088-1988, 5, 60-65
- [63] Anon. (1892). The Book of Trinity College, Dublin. 1591-1891. List of Delegates and Guests. Belfast, Marcus Ward & Co, p. 314
- [64] Groessens, E. & Groessens-Van Dyck, M.-C. (2001). De geologie. in Geschiedenis van de wetenschappen in België 1815-2000. La Renaissance du Livre, DEXIA, Vol. 1, 269-288
- [65] Groessens, E. (2008). Quelques pionniers de la Géologie officielle et la création d'un Service géologique de Belgique. Travaux du Comité Français d'Histoire de la Géologie (COFRHIGEO), Troisième Série, XXII, 1, 1-25
- [66] Renard, A.-F. (1896). Les Fondateurs de la Minéralogie. Extrait de la Revue des Questions scientifiques. Louvain, Imprimerie Polleunis & Ceuterick, 27 pp.

- [67] Renard, A.-F. & Stöber, F. (1900). Notions de Minéralogie. Librairie Générale de A. Hoste, Ed., 374 pp.
- [68] Hellens, F. (1935). Frédéric. Gallimard, Paris, 253 pp.
- [69] Hellens, F. (1953). Les marées de l'Escaut. Albin Michel, Paris, 301 pp.
- [70] De Maret, P. (2006). L'Université Libre de Bruxelles et la Franc-maçonnerie: destins croisés. *in* Tyssens, J. Les Trésors du Temple. Le Musée belge de la Franc-maçonnerie, p. 120-125
- [71] Renard, A.-F. (1897). La Géographie dans l'Enseignement Supérieur en Belgique. Bulletin de la Société Belge de Géologie, Paléontologie et d'Hydrologie, XI, Mémoires, 221-250
- [72] Schelfhout, C. E. (1996). Les Gerlache. Trois générations d'explorateurs polaires. Ed. de la Dyle, St. Martens-Latem, 446 pp.
- [73] Arctowski, H. & Renard, A.-F. (1901). Notice préliminaire sur les sédiments marins recueillis par l'Expédition de la 'Belgica'. Extrait des Mémoires couronnés et autres Mémoires, Acad. Royale de Belgique, LXI, 30 pp., 1 map.
- [74] Sartori, R. (2003). Luigi Ferdinando Marsili, founding father of oceanography. In Vai G.B. & Cavazza W., eds. Four Centuries of the Word Geology. Ulisse Aldrovandi 1603 in Bologna. Minerva Ed. 169-177.
- [75] Van Rensbergen, P., Depreiter, D., Pannemans, B., Moerkerke, G., Van Rooij, D., Marsset, B., Akhmanov, G., Blinova, V., Ivanov, M., Rachidi, M., Magalhaes, V., Pinheiro, L., Cunha, M. and Henriët, J.P. (2005). The El Arraiche mud volcano field at the Moroccan Atlantic slope, Gulf of Cadiz. Marine Geology 219, 1-17.